SCIENCE

FRIDAY, DECEMBER 8, 1899.

CONTENTS:

MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*THE HIGHEST AIM OF THE PHYSICIST.**

GENTLEMEN AND FELLOW PHYSICISTS OF AMERICA: We meet to day on an occasion which marks an epoch in the history of physics in America; may the future show that it also marks an epoch in the history of the science which this Society is organized to cultivate! For we meet here in the interest of a science which above all sciences deals with the foundation of the Universe, with the constitution of matter from which everything in the Universe is made and with the ether of space by which alone the various portions of matter forming the Universe affect each other even at such distances as we may never expect to traverse, whatever the progress of our science in the future.

We, who have devoted our lives to the solution of problems connected with physics, now meet together to help each other and to forward the interests of the subject which we love. A subject which appeals most strongly to the better instincts of our nature and the problems of which tax our minds to the limit of their capacity and suggest the grandest and noblest ideas of which they are capable.

In a country where the doctrine of the equal rights of man has been distorted to mean the equality of man in other respects,

* Address delivered to the Physical Society of America by the President, at its meeting in New York, October 28, 1899.

we form a small and unique body of men, a new variety of the human race as one of our greatest scientists calls it, whose views of what constitutes the greatest achievement in life are very different from those around us. In this respect we form an aristocracy, not of wealth, not of pedigree, but of intellect and of ideals, holding him in the highest respect who adds the most to our knowledge or who strives after it as the highest good.

Thus we meet together for mutual sympathy and the interchange of knowledge, and may we do so ever with appreciation of the benefits to ourselves and possibly to our science. Above all, let us cultivate the idea of the dignity of our pursuit so that this feeling may sustain us in the midst of a world which gives its highest praise, not to the investigation in the pure etherial physics which our Society is formed to cultivate, but to one who uses it for satisfying the physical rather than the intellectual needs of mankind. He who makes two blades of grass grow where one grew before is the benefactor of mankind; but he who obscurely worked to find the laws of such growth is the intellectual superior as well as the greater benefactor of the two.

How stands our country, then, in this respect? My answer must still be, now, as it was fifteen years ago, that much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs and but little thought and money is given to the grander portion of the subject which appeals to our intellect alone. But your presence here gives evidence that such a condition is not to last forever.

Even in the past we have a few names whom scientists throughout the world delight to honor. Franklin, who almost revolutionized the science of electricity by a few simple but profound experiments. Count Rumford, whose experiments almost demonstrated the nature of heat. Henry, who might have done much for the progress of physics had he published more fully the results of his investigations. Mayer, whose simple and ingenious experiments have been a source of pleasure and profit to many. This is the meager list of those whom death allows me to speak of and who have earned mention here by doing something for the progress of our science. And yet the record has been searched for more than a hundred years. How different had I started to record those who have made useful and beneficial inventions!

But I know, when I look in the faces of those before me, where the eager intellect and high purpose sit enthroned on bodies possessing the vigor and strength of youth, that the writer of a hundred years hence can no longer throw such a reproach upon our country. Nor can we blame those who have gone before us. The progress of every science shows us the condition of its growth. Very few persons, if isolated in a semi-civilized land, have either the desire or the opportunity of pursuing the higher branches of science. Even if they should be able to do so, their influence on their science depends upon what they publish and make known to the world. A hermit philosopher we can imagine might make many useful discoveries. Yet, if he keeps them to himself, he can never claim to have benefited the world in any degree. His unpublished results are his private gain, but the world is no better off until he has made them known in language strong enough to call attention to them and to convince the world of their truth. Thus, to encourage the growth of any science, the best thing we can do is to meet together in its interest, to discuss its problems, to criticize each other's work and, best of all, to provide means by which the better portion of it may be made known to the world. Furthermore, let us encourage discrimination in our thoughts

and work. Let us recognize the eras when great thoughts have been introduced into our subject and let us honor the great men who introduced and proved them correct. Let us forever reject such foolish ideas as the equality of mankind and carefully give the greater credit to the greater man. So, in choosing the subjects for our investigation, let us, if possible, work upon those subjects which will finally give us an advanced knowledge of some great subject. I am aware that we cannot always do this ; our ideas will often flow in side channels; but, with the great problems of the Universe before us, we may sometime be able to do our share toward the greater end.

What is matter; what is gravitation; what is ether and the radiation through it; what is electricity and magnetism ; how are these connected together and what is their relation to heat? These are the greater problems of the universe. But many infinitely smaller problems we must attack and solve before we can even guess at the solution of the greater ones.

In our attitude toward these greater problems how do we stand and what is the foundation of our knowledge?

Newton and the great array of astronomers who have succeeded him have proved that, within planetary distances, matter attracts all others with a force varying inversely as the square of the distance. But what sort of proof have we of this law? It is derived from astronomical observations on the planetary orbits. It agrees very well within these immense spaces; but where is the evidence that the law holds for smaller distances? We measure the lunar distance and the size of the earth and compare the force at that distance with the force of gravitation on the earth's surface. But to do this we must compare the matter in the earth with that in the sun. This we can only do by *assuming* the law to be proved. Again, in descending from the earth's gravitation to that of two small bodies, as in the Cavendish experiment, we *assume* the law to hold and deduce the mass of the earth in terms of our unit of mass. Hence, when we say that the mass of the earth is $5\frac{1}{2}$ times that of an equal volume of water we *assume* the law of gravitation to be that of Newton. Thus a proof of the law from planetary down to terrestrial distances is physically impossible.

Again, that portion of the law which says that gravitational attraction is proportional to the quantity of matter, which is the same as saying that the attraction of one body by another is not affected by the presence of a third, the feeble proof that we give by weighing bodies in a balance in different positions with respect to each other cannot be accepted on a larger scale. When we can tear the sun into two portions and prove that either of the two halves attracts half as much as the whole, then we shall have a proof worth mentioning.

Then as to the relation of gravitation and time what can we say? Can we for a moment suppose that two bodies moving through space with great velocities have their gravitation unaltered? I think not. Neither can we accept Laplace's proof that the force of gravitation acts instantaneously through space, for we can readily imagine some compensating features unthought of by Laplace.

How little we know then of this law which has been under observation for two hundred years!

Then as to matter itself how have our views changed and how are they constantly changing. The round hard atom of Newton which God alone could break into pieces has become a molecule composed of many atoms, and each of these smaller atoms has become so elastic that after vibrating 100,000 times its amplitude of vibration is scarcely diminished. It has become so complicated that it can vibrate

with as many thousand notes. We cover the atom with patches of electricity here and there and make of it a system compared with which the planetary system, nay the universe itself, is simplicity. Nay more: some of us even claim the power, which Newton attributed to God alone, of breaking the atom into smaller pieces whose size is left to the imagination. Where, then, is that person who ignorantly sneers at the study of matter as a material and gross study? Where, again, is that man with gifts so God-like and mind so elevated that he can attack and solve its problem?

To all matter we attribute two properties, gravitation and inertia. Without these two matter cannot exist. The greatest of the natural laws states that the power of gravitational attraction is proportional to the mass of the body. This law of Newton, almost neglected in the thoughts of physicists, undoubtedly has vast import of the very deepest meaning. Shall it mean that all matter is finally constructed of uniform and similar primordial atoms or can we find some other explanation?

That the molecules of matter are not round, we know from the facts of crystallography and the action of matter in rotating the plane of polarization of light.

That portions of the molecules and even of the atoms are electrically charged, we know from electrolysis, the action of gases in a vacuum tube and from the Zeeman effect.

That some of them act like little magnets, we know from the magnetic action of iron, nickel and cobalt.

That they are elastic, the spectrum shows, and that the vibrating portion carries the electrified charge with it is shown by the Zeeman effect.

Here, then, we have made quite a start in our problem: but how far are we from the complete solution? How can we imagine the material of which ordinary or primordial atoms are made, dealing as we do only with aggregation of atoms alone? Forever beyond our sight, vibrating an almost infinite number of times in a second, moving hither and yon with restless energy at all temperatures beyond the absolute zero of temperature, it is certainly a wonderful feat of human reason and imagination that we know as much as we do at present. Encouraged by these results, let us not linger too long in their contemplation but press forward to the new discoveries which await us in the future.

Then as to electricity, the subtile spirit of the amber, the demon who reached out his gluttonous arms to draw in the light bodies within his reach, the fluid which could run through metals with the greatest ease but could be stopped by a frail piece of glass! Where is it now? Vanished, thrown on the waste heap of our discarded theories to be replaced by a far nobler and exalted one of action in the ether of space.

And so we are brought to consider that other great entity—the ether: filling all space without limit, we imagine the ether to be the only means by which two portions of matter distant from each other can have any mutual action. By its means we imagine every atom in the universe to be bound to every other atom by the force of gravitation and often by the force of magnetic and electric action, and we conceive that it alone conveys the vibratory motion of each atom or molecule out into space to be ever lost in endless radiation, passing out into infinite space or absorbed by some other atoms which happen to be in its path. By it all electromagnetic energy is conveyed from the feeble attraction of the rubbed amber through the many thousand horsepower conveyed by the electric wires from Niagara to the mighty rush of energy always flowing from the Sun in a flood of radiation. Actions feeble and actions mighty from inter-

molecular distances through interplanetary and interstellar distances until we reach the mighty distances which bound the Universe—all have their being in this wondrous ether.

And yet, however wonderful it may be, its laws are far more simple than those of matter. Every wave in it, whatever its length or intensity, proceeds onwards in it according to well known laws, all with the same speed, unaltered in direction from its source in electrified matter, to the confines of the Universe unimpaired in energy unless it is disturbed by the presence of matter. However the waves may cross each other, each proceeds by itself without interference with the others.

So with regard to gravitation, we have no evidence that the presence of a third body affects the mutual attraction of two other bodies, or that the presence of a third quantity of electricity affects the mutual attraction of two other quantities. The same for magnetism.

For this reason the laws of gravitation and of electric and magnetic action including radiation are the simplest of all laws when we confine them to a so-called vacuum, but become more and more complicated when we treat of them in space containing matter.

Subject the ether to immense electrostatic, magnetic or gravitational forces and we find absolutely no signs of its breaking down or even of change of properties. Set it into vibration by means of an intensely hot body like the sun and it conveys many thousand horse-power for each square foot of surface as quietly and with apparently unchanged laws as if it were conveying the energy of a tallow dip.

Again, subject a millimeter of ether to the stress of many thousand, nay even a million, volts and yet we see no signs of breaking down.

Hence the properties of the ether are of ideal simplicity and lead to the simplest of natural laws. All forces which act at a distance, always obey the law of the inverse square of the distance, and we have also the attraction of any number of parts placed near each other equal to the arithmetical sum of the attractions when those parts are separated. So also the simpler law of etherial waves which has been mentioned above.

At the present time, through the labors of Maxwell supplemented by those of Hertz and others, we have arrived at the great generalization that all wave disturbances in the ether are electromagnetic in their nature. We know of little or no etherial disturbance which can be set up by the motion of matter alone: the matter must be electrified in order to have sufficient hold on the ether to communicate its motion to the ether. The Zeeman effect even shows this to be the case where molecules are concerned and when the period of vibration is immensely great. Indeed the experiment on the magnetic action of electric convection shows the same thing. By electrifying a disc in motion it appears as if the disc holds fast to the ether and drags it with it, thus setting up the peculiar etherial motion known as magnetism.

Have we not another case of a similar nature when a huge gravitational mass like that of the earth revolves on its axis? Has not matter a feeble hold on the ether sufficient to produce the earth's magnetism?

But the experiment of Lodge to detect such an action apparently showed that it must be very feeble. Might not his experiment have succeeded had he used an electrical revolving disc?

To detect something dependent on the relative motion of the ether and matter has been and is the great desire of physicists. But we always find that, with one possible exception, there is always some compensating feature which renders our efforts use-

less. This one experiment is the aberration of light, but even here Stokes has shown that it may be explained in either of two ways: first, that the earth moves through the ether of space without disturbing it, and second, if it carries the ether with it by a kind of motion called irrotational. Even here, however, the amount of action probably depends upon *relative* motion of the luminous source to the recipient telescope.

So the principle of Döppler depends also on this relative motion and is independent of the ether.

The result of the experiments of Foucault on the passage of light through moving water can no longer be interpreted as due to the partial movement of the ether with the moving water, an inference due to imperfect theory alone. The experiment of Lodge, who attempted to set the ether in motion by a rapidly rotating disc, showed no such result.

The experiment of Michelson to detect the etherial wind, although carried to the extreme of accuracy, also failed to detect any relative motion of the matter and the ether.

But matter with an electrical charge holds fast to the ether and moves it in the manner required for magnetic action.

When electrified bodies move together through space or with reference to each other we can only follow their mutual actions through very slow and uniform velocities. When they move with velocities comparable with that of light, equal to it or even beyond it, we calculate their mutual actions or action on the ether only by the light of our imagination unguided by experiment. The conclusions of J. J. Thomson, Heaviside and Hertz are all results of the imagination and they all rest upon assumptions more or less reasonable but always assumptions. A mathematical investigation always obeys the law of the conservation of knowledge: we never get out more from it than we put in. The knowledge may be changed in form, it may be clearer and more exactly stated, but the total amount of the knowledge of nature given out by the investigation is the same as we started with. Hence we can never predict the result in the case of velocities beyond our reach, and such calculations as the velocity of the cathode rays from their electromagnetic action has a great element of uncertainty which we should do well to remember.

Indeed, when it comes to exact knowledge, the limits are far more circumscribed.

How is it, then, that we hear physicists and others constantly stating what will happen beyond these limits? Take velocities, for instance, such as that of a material body moving with the velocity of light. There is no known process by which such a velocity can be obtained even though the body fell from an infinite distance upon the largest aggregation of matter in the Universe. If we electrify it, as in the cathode rays, its properties are so changed that the matter properties are completely masked by the electromagnetic.

It is a common error which young physicists are apt to fall into to obtain a law, a curve or a mathematical expression for given experimental limits and then to apply it to points outside those limits. This is sometimes called extrapolation. Such a process, unless carefully guarded, ceases to be a reasoning process and becomes one of pure imagination specially liable to error when the distance is too great.

But it is not my purpose to enter into detail. What I have given suffices to show how little we know of the profounder questions involved in our subject.

It is a curious fact that, having minds tending to the infinite, with imaginations unlimited by time and space, the limits of our exact knowledge are very small indeed.

In time we are limited by a few hundred or possibly thousand years: indeed the limit in our science is far less than the smaller of these periods. In space we have exact knowledge limited to portions of our earth's surface and a mile or so below the surface, together with what little we can learn from looking through powerful telescopes into the space beyond. In temperature our knowledge extends from near the absolute zero to that of the sun but exact knowledge is far more limited. In pressures we go from the Crookes vacuum still containing myriads of flying atoms to pressures limited by the strength of steel but still very minute compared with the pressures at the center of the earth and sun, where the hardest steel would flow like the most limpid water. In velocities we are limited to a few miles per second. In forces to possibly 100 tons to the square inch. In mechanical rotations to a few hundred times per second.

All the facts which we have considered, the liability to error in whatever direction we go, the infirmity of our minds in their reasoning power, the fallibility of witnesses and experimenters, lead the scientist to be specially sceptical with reference to any statement made to him or any so-called knowledge which may be brought to his attention. The facts and theories of our science are so much more certain than those of history, of the testimony of ordinary people on which the facts of ordinary history or of legal evidence rest, or of the value of medicines to which we trust when we are ill, indeed to the whole fabric of supposed truth by which an ordinary person guides his belief and the actions of his life, that it may seem ominous and strange if what I have said of the imperfections of the knowledge of physics is correct. How shall we regulate our minds with respect to it: there is only one way that I know of and that is to avoid the discontinuity of the ordinary, indeed the so-called cultivated legal mind. There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.

The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases: the ideal scientific mind, however, has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as, if possible, to always keep it in its proper relation to truth and error. Thus the fluid nature of electricity was once in a compartment near the truth. Faraday's and Maxwell's researches have now caused us to move it to a compartment nearly up to that of absolute error.

So the law of gravitation within planetary distances is far toward absolute truth, but may still need amending before it is advanced farther in that direction.

The ideal scientific mind, therefore, must always be held in a state of balance which the slightest new evidence may change in one direction or another. It is in a constant state of skepticism, knowing full well that nothing is certain. It is above all an agnostic with respect to all facts and theories of science as well as to all other so-called beliefs and theories.

Yet it would be folly to reason from this that we need not guide our life according to the approach to knowledge that we possess. Nature is inexorable; it punishes the child who unknowingly steps off a precipice quite as severely as the grown scientist who steps over, with full knowledge of all the

laws of falling bodies and the chances of their being correct. Both fall to the bottom and in their fall obey the gravitational laws of inorganic matter, slightly modified by the muscular contortions of the falling object but not in any degree changed by the previous belief of the person. Natural laws there probably are, rigid and unchanging ones at that. Understand them and they are beneficent: we can use them for our purposes and make them the slaves of our desires. Misunderstand them and they are monsters who may grind us to powder or crush us in the dust. Nothing is asked of us as to our belief: they act unswervingly and we must understand them or suffer the consequences. Our only course, then, is to act according to the chances of our knowing the right laws. If we act correctly, right; if we act incorrectly, we suffer. If we are ignorant we die. What greater fool, then, than he who states that belief is of no consequence provided it is sincere.

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison? Why, then, has he not used it? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance.* The remedy is yet unknown. The physician is waiting for others to discover it or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth. Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of boors and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease.

But the true lover of physics needs no such spur to his actions. The cure of disease is a very important object and nothing can be nobler than a life devoted to its cure.

The aims of the physicist, however, are in part purely intellectual; he strives to understand the Universe on account of the intellectual pleasure derived from the pursuit, but he is upheld in it by the knowl-

edge that the study of nature's secrets is the ordained method by which the greatest good and happiness shall finally come to the human race.

Where, then, are the greatest laboratories of research in this city, in this country, nay, in the world? We see a few miserable structures here and there occupied by a few starving professors who are nobly striving to do the best with the feeble means at their disposal. But where in the world is the institute of pure research in any department of science with an income of $100,000,000 per year. Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But $100,000,000 per year is but the price of an army or a navy designed to kill other people. Just think of it, that one per cent. of this sum seems to most people too great to save our children and descendants from misery and even death!

But the twentieth century is near—may we not hope for better things before its end? May we not not hope to influence the public in this direction?

Let us go forward, then, with confidence in the dignity of our pursuit. Let us hold our heads high with a pure conscience while we seek the truth, and may the American Physical Society do its share now and in generations yet to come in trying to unravel the great problem of the constitution and laws of the Universe.

HENRY A. ROWLAND.

CRUISE OF THE ALBATROSS.

THE following letter has been received by the U. S. Fish Commission from Professor Alexander Agassiz. It is dated Papeete Harbor, Tahiti Island, September 30, 1899, and gives an account of the voyage of the *Albatross* up to that time.

I arrived at San Francisco on August 20th, and after consulting with Commander Moser we decided to leave on Wednesday, the 23d. Everything shipped from the east had arrived with the exception of the tow nets sent me by Dr. Kramer, and the deep-sea nets kindly ordered for me by Professor Chun of Leipzig. Captain Moser and I decided not to make any soundings nor do any deep-sea work until we had passed beyond the lines of soundings already run by the *Albatross* and *Thetis* between California and the Hawaiian Islands.

In latitude 31° 10′ N., and longitude 125° W., we made our first sounding in 1955 fathoms, about 320 miles from Point Conception, the nearest land. We occupied 26 stations until we reached the northern edge of the plateau from which rise the Marquesas Islands, having run from station No. 1, a distance of 3800 miles, in a straight line.

At station No. 2 the depth had increased to 2368 fathoms, the nearest land, Guadeloupe Island, being about 450 miles, and Point Conception nearly 500 miles distant. The depth gradually increased to 2628, 2740, 2810, 2881, 3003, and 3088 fathoms, the last in lat. 16° 38′ N., long. 130 14′ W., the deepest sounding we obtained thus far in the unexplored part of the Pacific through which we are passing. From that point the depths varied from 2883 to 2690 and 2776, diminishing to 2583, and gradually passing to 2440, 2463, and 2475 fathoms, until off the Marquesas, in lat. 7° 58′ S., long. 139° 08′ W., the depth became 2287 fathoms. It then passed to 1929, 1802, and 1040 fathoms, in lat. 8° 41′ S, long. 139° 46′ W., Nukuhiva Island being about 30 miles distant. Between Nukuhiva and Houa-Houna (Ua-Huka) islands we obtained 830 fathoms, and 5 miles south of Nukuhiva 687 fathoms. When leaving Nukuhiva for the Paumotus we sounded in 1284 fathoms about 9 miles south of that island. These soundings seem to show that this part of the Marquesas rises from a